Subhalo Abundance Matching in the Bolshoi Simulation Tested Against SDSS DR7 Galaxies

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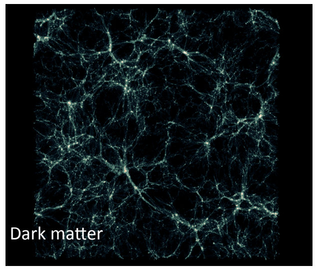
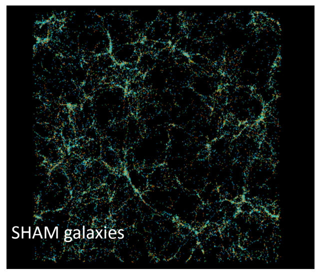
Overview

- The connection between galaxies and their dark matter halos is critical to understanding galaxy formation.
- Recent progress in simulations and large galaxy surveys allow more precise tests than were previously possible.
- Subhalo abundance matching (SHAM) is a simple but effective approach for connecting simulated dark matter halos with galaxies. The only data input needed is the luminosity (or stellar mass) function.
- Unlike typical semi-analytical models, SHAM can reproduce galaxy clustering with just one to a few parameters. This simplifies interpretation.
- The only necessary parameter for SHAM to reproduce the clustering of galaxies is a scatter in luminosity. We estimate that the scatter is roughly 0.16 dex in luminosity.
- SHAM reproduces other statistics such as the conditional luminosity function. However, differences in detail suggest that the satellite galaxies must be treated more carefully.

The Abundance Matching Method

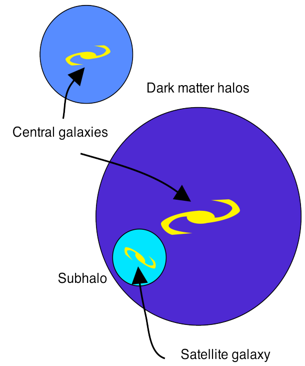




Simulation

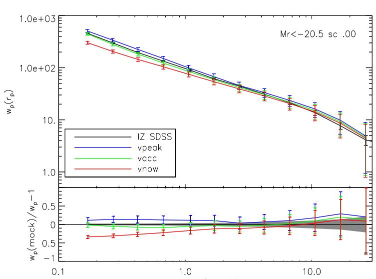
For our study, we use the Bolshoi simulation produced by Klypin et al, a cosmological box of size 250 Mpc/h on a side, with mass resolution of about 10^8 $M_\odot$ and ~kpc force resolution. This is capable of resolving dark matter halos slightly smaller than the Small Magellanic Cloud.

Subhalo Abundance Matching



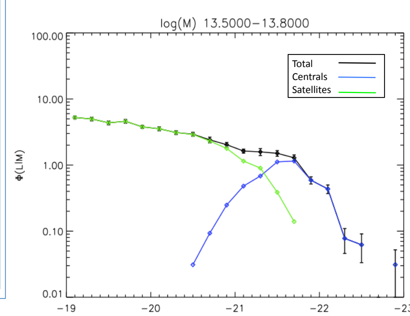
- We use subhalo abundance matching to assign galaxies to halos. Given a luminosity function, halos are assigned galaxies so that the most massive halo hosts the most luminous galaxy, the second most massive hosts the second most luminous, and so on.
- This approach may incorporate scatter in the luminosity. We use the maximum circular velocity (v_{max}) of a halo as a proxy for the mass.
- In the case of satellite galaxies, we may use the v_{max} at accretion (v_{acc}) or the maximum value in the halo's history (v_{peak}) to handle the difference between halo and galaxy stripping.

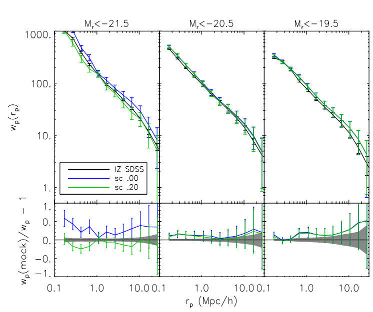
Testing SHAM with the SDSS



Projected Correlation Function

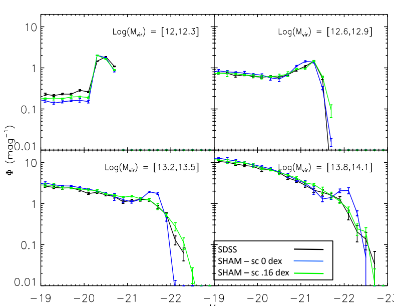
- The two-point projected correlation function is a useful test of the performance of the SHAM technique. The small scales (<1 Mpc) are dominated by pairs of galaxies within a single dark matter halo. Large scales emphasize the two-halo term: pairs between different host halos. The current galaxy correlation function can be seen to the left, with the SDSS measurement. In particular, using v_{peak} or v_{acc} tends to enhance the small-scale clustering.
- Due to the effect of the galaxy bias, the brighter samples (lower left) are more clustered, and more sensitive to scatter, than those which are dimmer than L*. Above L*, scatter can be constrained to ~0.16 dex. (Below L*, scatter has only a small impact on the galaxy-galaxy clustering.)





Conditional Luminosity Function

- The conditional luminosity function (CLF) is defined to be average number of galaxies in a halo (not subhalo) of some mass, as a function of luminosity. Making this measurement requires producing a catalog of galaxy groups. An example from the SDSS is to the upper, showing how the CLF may be split into satellite and central parts.
- The lower plot shows how the CLF varies with halo mass. SHAM with v_{peak} reproduces the general form of the CLF, but scatter of roughly 0.16 dex is necessary.
- For the parameters that provide a good fit to the two-point statistics, SHAM predicts too many satellites in massive halos. This suggests additional stripping in massive halos needs to be accounted for in the model. We add a new parameter, omitting all subhalos whose present mass is less than some fraction *f* of their maximum mass prior to being accreted. The CLFs to the right show the result of placing such a cut, at *f*=0.1. This does not strongly impact the correlation function, leaving the preferred scatter around 0.16 dex.



References:

- Behroozi, P. S., Conroy, C., & Wechsler, R. H. 2010, ApJ, 717, 379
- Conroy, C., Wechsler, R. H., & Kravtsov, A. V. 2006, ApJ, 647, 201
- Klypin, A., Trujillo-Gomez, S., & Primack, J. 2010, ArXiv e-prints 1002.3660
- Tinker, J. et al. 2008, ApJ, 688, 709
- Yang, X., Mo, H. J., & van den Bosch, F. C. 2003, MNRAS, 339, 1057
- —. 2008, ApJ, 676, 248
- Zehavi, I., et al. 2005, ApJ, 630, 1
- —. 2010, ArXiv e-prints 1005.2413